

(12) **United States Patent**
Campbell et al.

(10) **Patent No.:** **US 7,499,279 B2**
(45) **Date of Patent:** **Mar. 3, 2009**

(54) **COLD PLATE STABILITY**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 11 days.

(21) Appl. No.: **11/741,852**

(22) Filed: **Apr. 30, 2007**

(65) **Prior Publication Data**

US 2008/0266799 A1 Oct. 30, 2008

(51) **Int. Cl.**
H05K 7/20 (2006.01)

(52) **U.S. Cl.** **361/702**; 361/699; 361/704; 165/80.4; 257/714; 257/718

(58) **Field of Classification Search** None
See application file for complete search history.

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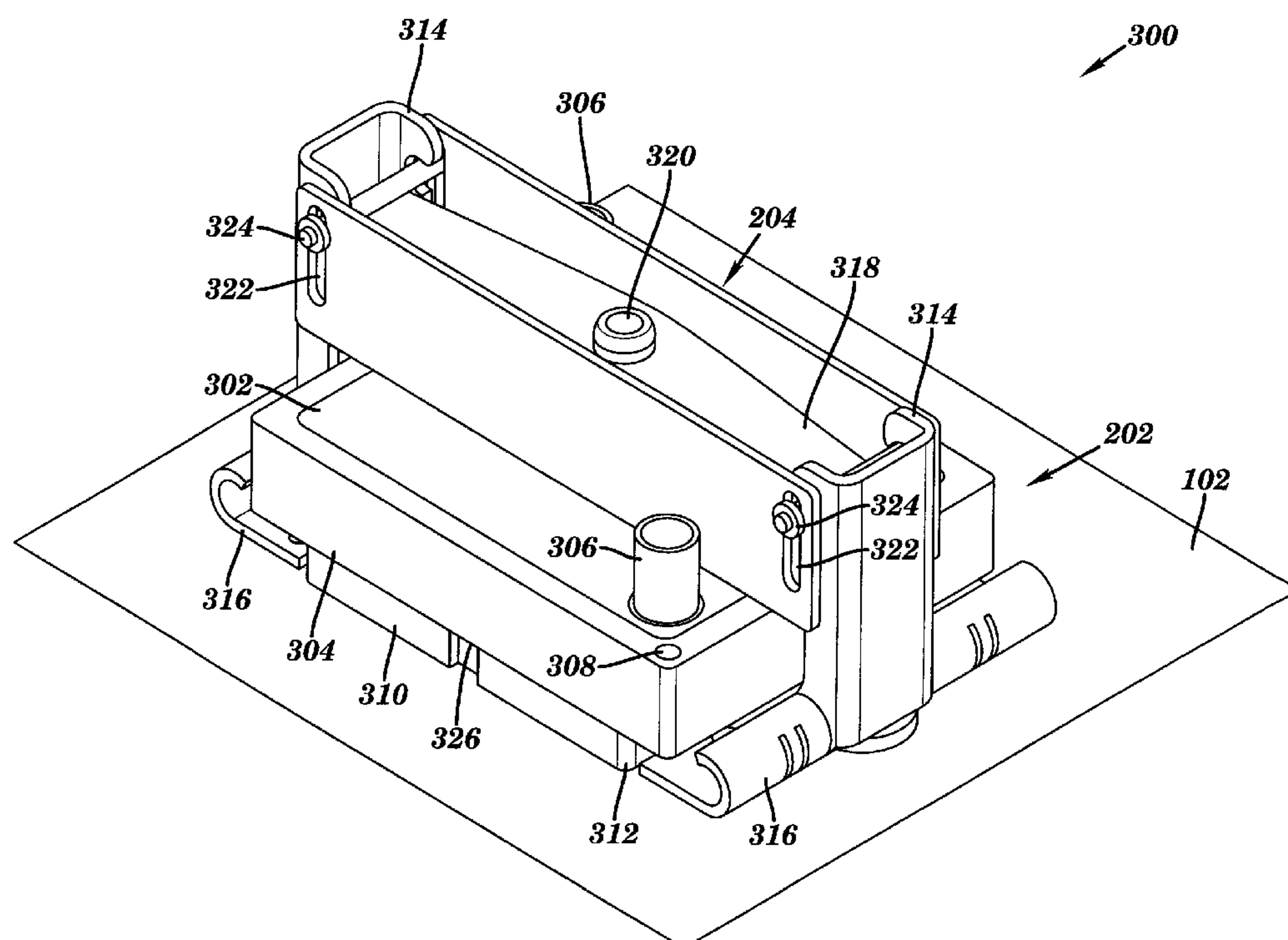
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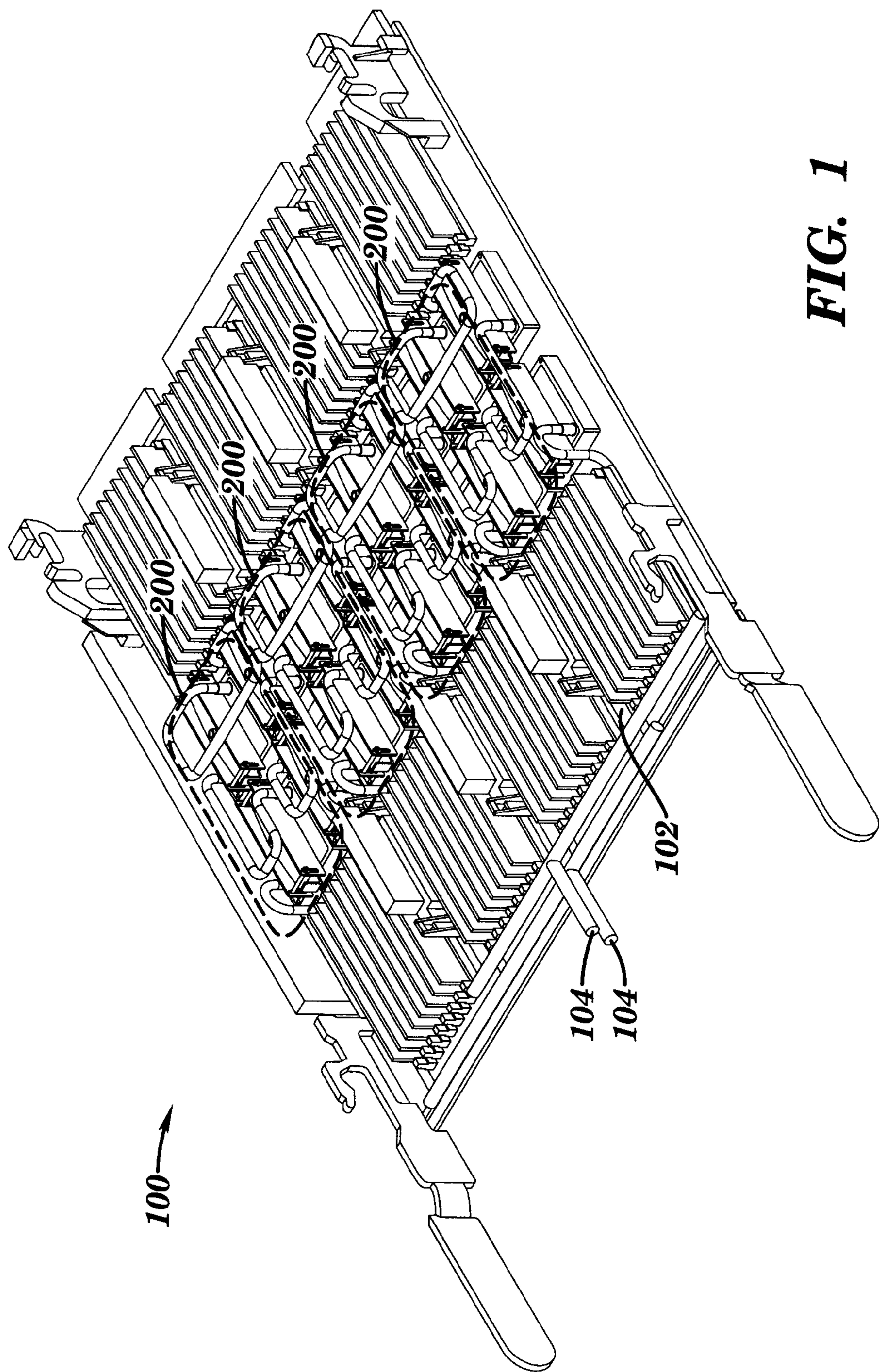
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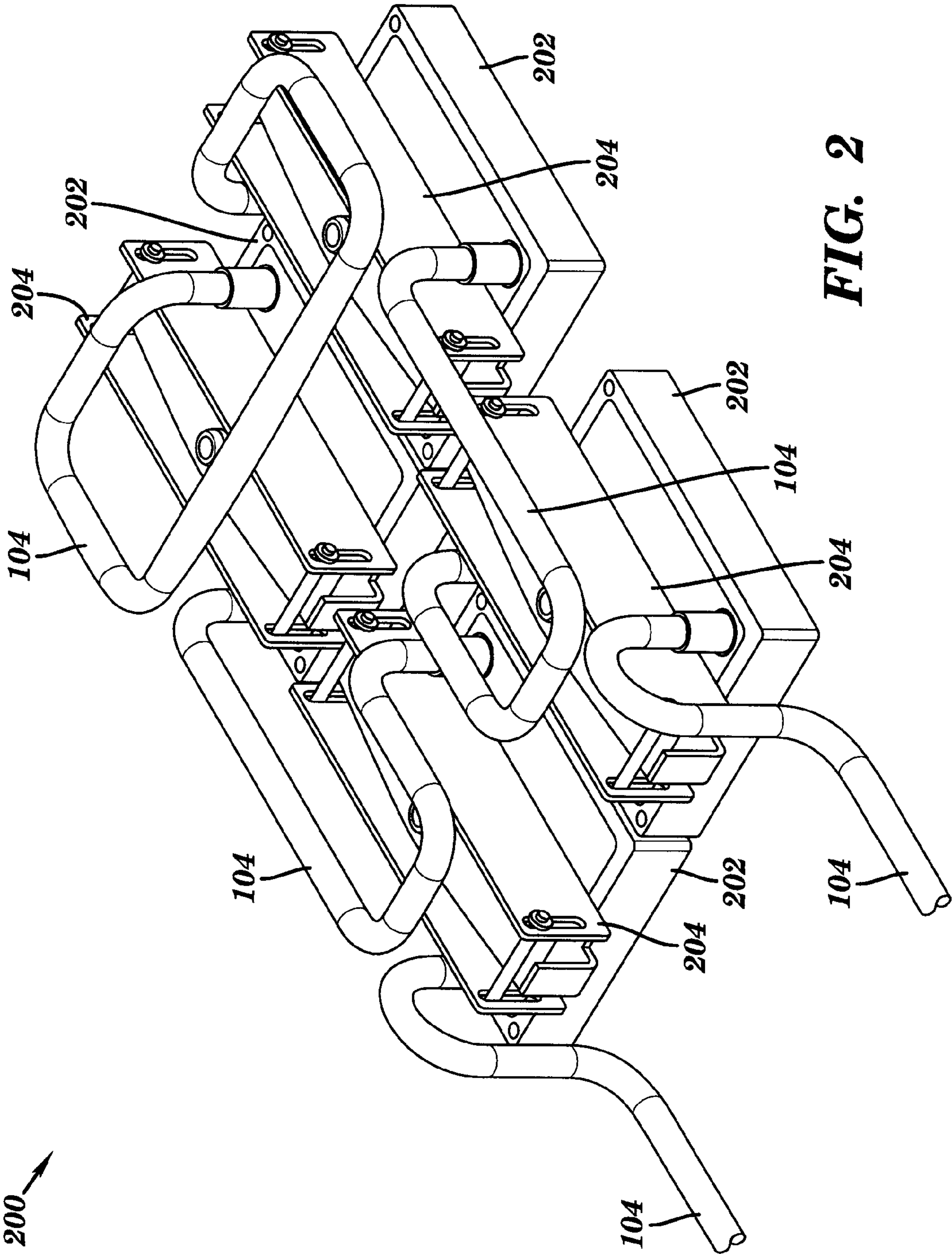
(57) **ABSTRACT**

A cold plate assembly includes a cold plate with at least two plumbing ports. The cold plate assembly further includes a spring plate assembly, which applies an actuation load to the cold plate. The actuation load is configured to mechanically actuate the cold plate to a module.

11 Claims, 7 Drawing Sheets







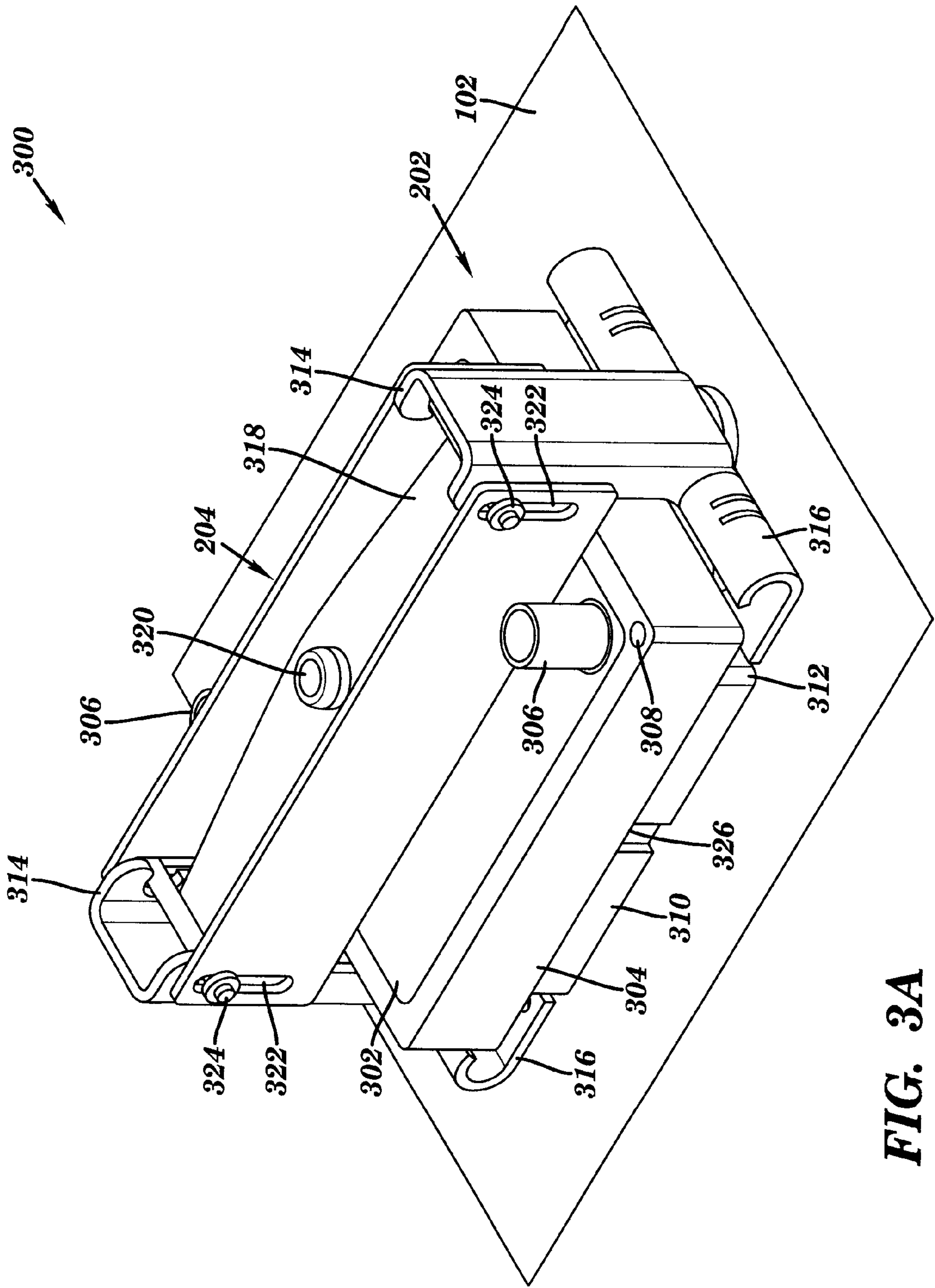
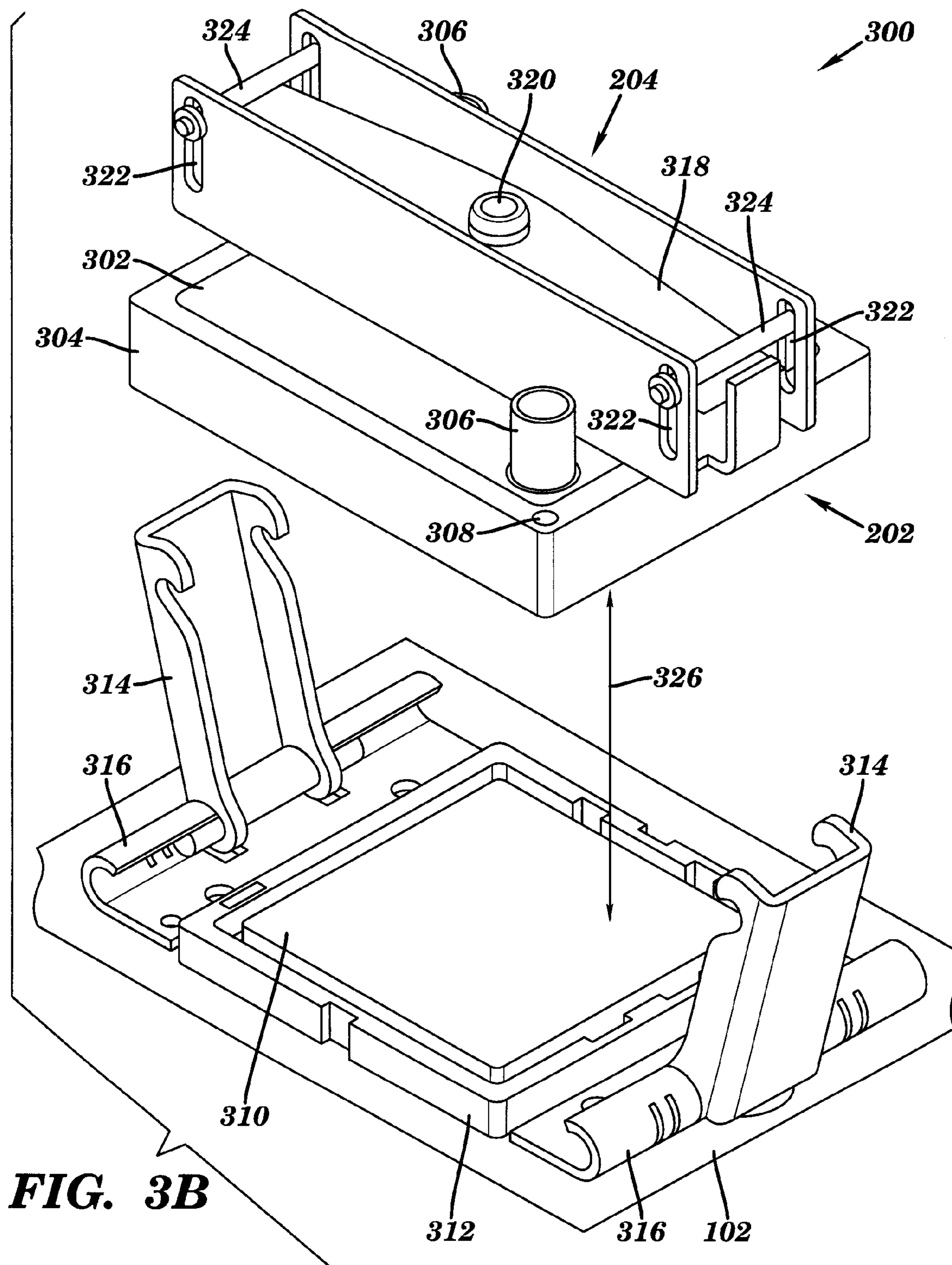


FIG. 3A



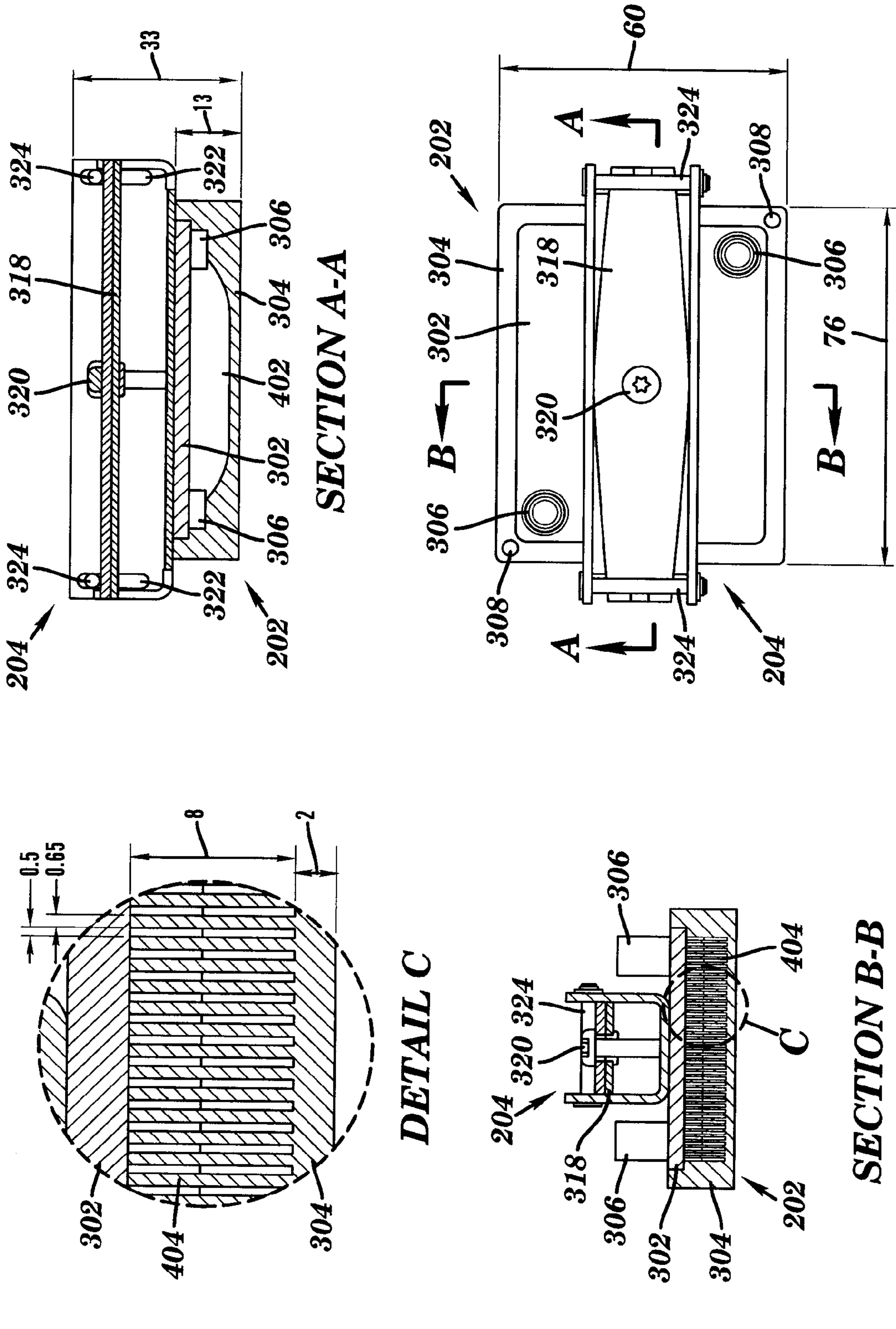
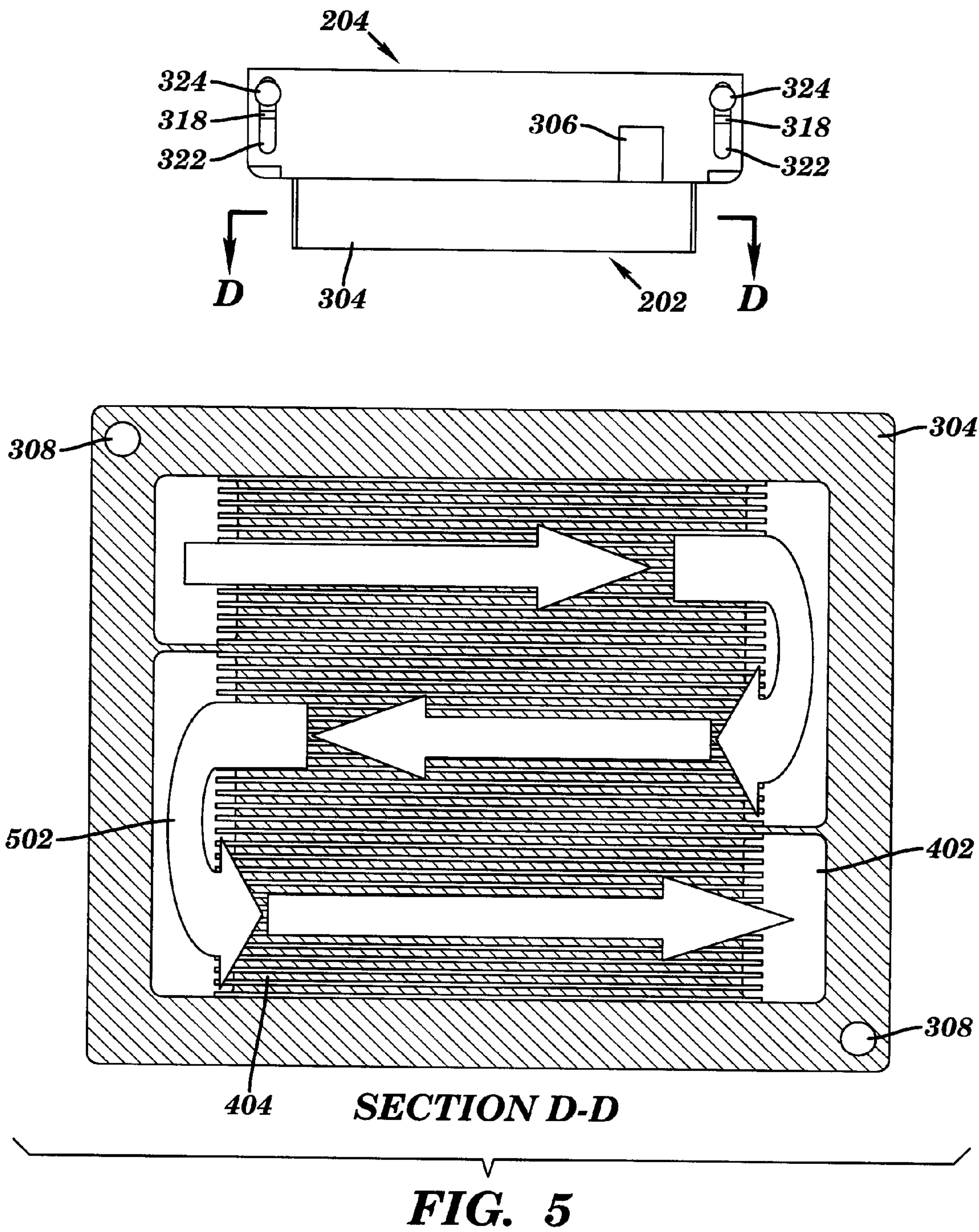
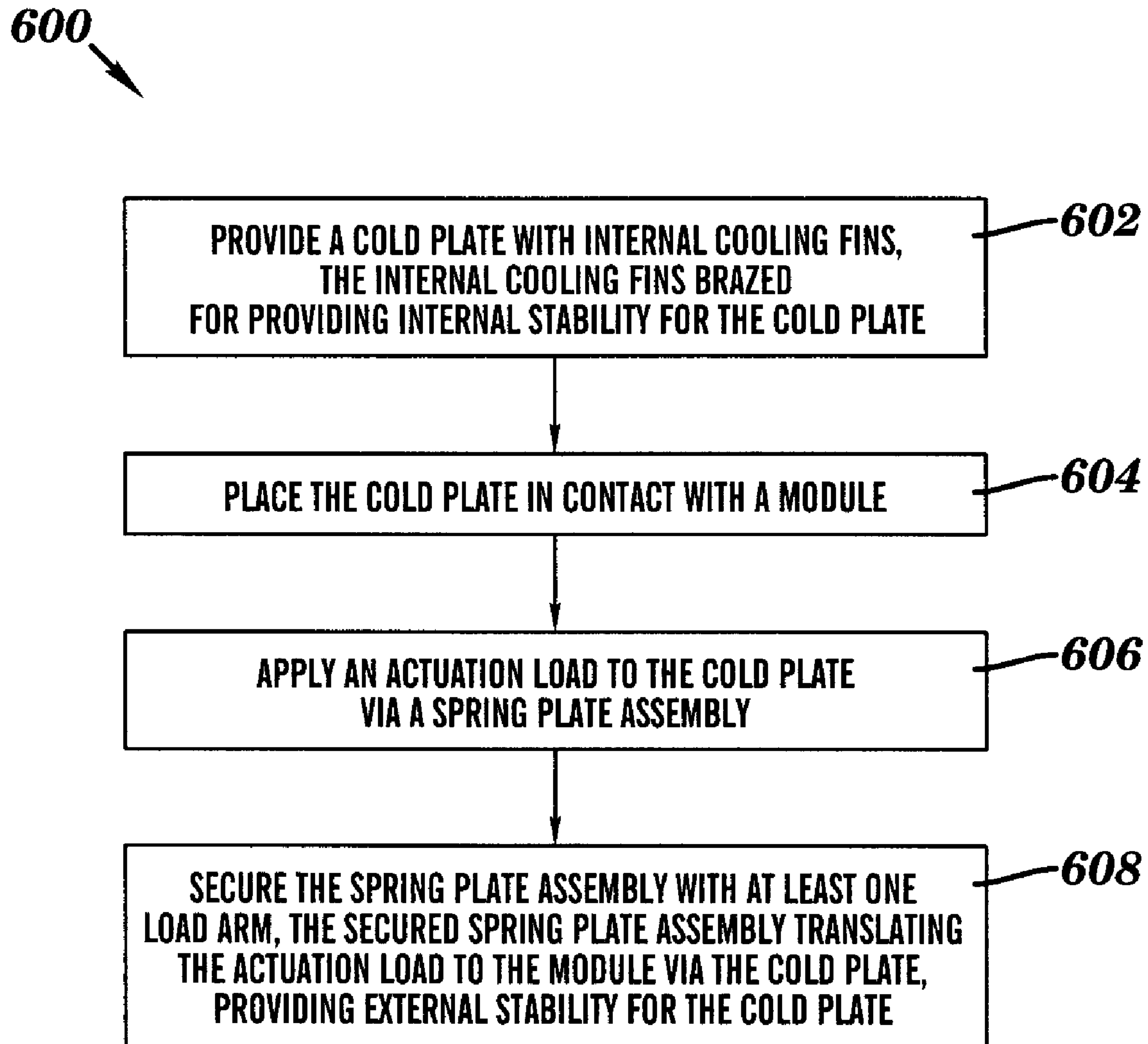


FIG. 4



**FIG. 6**

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COLD PLATE STABILITY**BACKGROUND OF THE INVENTION**

The present disclosure relates generally to integrated circuit heat dissipation devices, and, in particular, to methods and apparatuses for cold plate stability.

As high performance computers increase in performance, which may be measured in floating-point operations per second (FLOPS) or millions of instructions per second (MIPS), the associated microprocessors within the computers typically increase in both speed and required electrical power. As manufacturers have sought to integrate multiple microprocessors or other components within a single package, such as a multi-chip module (MCM) or other multi-core technologies, the associated number of electrical connections for such packages has grown. In order to reduce package size, many manufacturers have turned from pin grid array (PGA) and ball grid array (BGA) interfaces to land grid array (LGA) interfaces. An LGA interface may use pads instead of pins or balls to connect to a printed wire board (PWB) through a socket or similar interface. LGAs may be preferred over PGAs or BGAs due to larger contact points and higher connection densities, allowing for higher clock frequencies and more power contacts. However, since power consumed is dissipated as heat, LGAs may produce more heat than PGAs and BGAs of comparable size. With the combined challenges of more numerous and powerful microprocessors in a given package, limits of air-cooling may be exceeded as performance demands continue to increase. Moreover, traditional cold plate assemblies may not meet mechanical constraints of modern packages, particularly in a server environment where multiple packages may be installed in a physically confined space.

Since it is desirable for performance and reliability to maintain a module's active metallurgy at a specified temperature, advanced heat transfer structures and methods are needed to maintain both thermal and structural stability.

BRIEF SUMMARY OF THE INVENTION

Embodiments of the invention include a cold plate assembly. The cold plate assembly includes a cold plate with at least two plumbing ports. The cold plate assembly further includes a spring plate assembly, which applies an actuation load to the cold plate. The actuation load is configured to mechanically actuate the cold plate to a module.

Additional embodiments include a cold plate assembly that includes a cold plate with at least two plumbing ports and a spring plate assembly, which applies an actuation load to the cold plate. The cold plate includes a top component coupled to a bottom component and cooling fins brazed to at least one of the top component and the bottom component. The cooling fins provide a cooling fluid circulation path between the plumbing ports. The spring plate assembly includes at least one spring plate and an actuation screw, the actuation screw adjustable to set the actuation load. The cold plate assembly further includes at least one load arm, which locks the spring plate assembly onto the cold plate and maintains the actuation load.

Further embodiments include a method for providing cold plate stability. The method includes placing the cold plate in contact with a module, applying an actuation load to the cold plate via a spring plate assembly, and securing the spring plate assembly with at least one load arm. The secured spring plate assembly translates the actuation load to the module via the cold plate.

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Additional embodiments include a method for providing cold plate stability. The method includes placing the cold plate in contact with a module, applying an actuation load to the cold plate via a spring plate assembly, and securing the spring plate assembly with at least one load arm. The cold plate includes at least two plumbing ports, a top component coupled to a bottom component, and cooling fins brazed to at least one of the top component and the bottom component. The plumbing ports provide an inlet and an outlet for a cooling fluid. The cooling fins provide a cooling fluid circulation path between the two plumbing ports. The spring plate assembly includes at least one spring plate and an actuation screw, the actuation screw adjustable to set the actuation load. The secured spring plate assembly translates the actuation load to the module via the cold plate.

Other methods, apparatuses, and/or systems according to embodiments will be or become apparent to one with skill in the art upon review of the following drawings and detailed description. It is intended that all such additional methods, apparatuses, and/or systems be included within this description, be within the scope of the present invention, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter which is regarded as the invention is particularly pointed out and distinctly claimed in the claims at the conclusion of the specification. The foregoing and other objects, features, and advantages of the invention are apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a perspective view of a node with multiple quadrants of cold plate assemblies that are plumbed together in accordance with exemplary embodiments;

FIG. 2 is a perspective view of a quadrant of cold plate assemblies that are plumbed together in accordance with exemplary embodiments;

FIG. 3a is a perspective view of a cold plate assembly with load arms and a module subject to cooling in accordance with exemplary embodiments;

FIG. 3b is an exploded view of a cold plate assembly with load arms and a module subject to cooling in accordance with exemplary embodiments;

FIG. 4 includes a top view and side cross sectional views of the structure of a cold plate assembly in accordance with exemplary embodiments;

FIG. 5 is a top cross sectional view of the structure of a channel and manifold for a cold plate assembly in accordance with exemplary embodiments; and

FIG. 6 is a flow diagram describing a process for providing cold plate stability in accordance with exemplary embodiments.

The detailed description explains the preferred embodiments of the invention, together with advantages and features, by way of example with reference to the drawings.

DETAILED DESCRIPTION OF THE INVENTION

Disclosed herein are apparatuses and methods for cold plate stability. While there are a wide variety of electronic packaging and interface options, such as pin grid array (PGA), ball grid array (BGA), land grid array (LGA), and hybrid LGA, a common issue exists in removing heat dissipated from modules utilizing these technologies. Greater module size, module density, and clock frequencies typically result in a greater production of heat. As a single module can contain multiple components, such as a multi-chip module

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(MCM) or multi-core module of microprocessors, memory, and the like, the heat dissipated from such a module can be substantial. Moreover, an LGA module (interfacing via pad connections) or a hybrid LGA module (interfacing via pad and solder connections) may require a large actuation load (e.g., about 60 grams per electrical connection point) to maintain electrical continuity between the module and a printed wire board (PWB) through which the module interfaces to other system components. In exemplary embodiments, the cold plate assembly disclosed herein provides both cooling and an actuation load for a variety of module designs, such as an LGA or hybrid LGA module, through an enhanced stability structure that supports fluid cooling and interconnections to additional cold plate assemblies.

Turning now to FIG. 1, a perspective view of a node 100 with multiple quadrants of cold plate assemblies 200 that are plumbed together is depicted in accordance with exemplary embodiments. In exemplary embodiments, the node 100 is a processing assembly including processing system components such as memory modules, busses, and microprocessor modules affixed to a printed wire board (PWB) 102. The node 100 may be a subsystem of a larger system such as a main-frame computer. In exemplary embodiments, the PWB 102 supports coupling modules, such as hybrid LGA modules, to the PWB 102. The PWB 102 may support multiple or mixed packaging and interfacing technologies. The node 100 may include multiple quadrants of cold plate assemblies 200 for cooling multiple modules. In exemplary embodiments, plumbing lines 104 route a cooling fluid, such as water, through each of the quadrants of cold plate assemblies 200, providing a cooling fluid circulation path through the node 100. While the configuration of cold plate assemblies depicted in FIG. 1 includes four quadrants of cold plate assemblies 200, the scope of the invention is not so limited. To the contrary, there may be any number of quadrants of cold plate assemblies 200, or alternate plumbing schemes between cold plate assemblies. Moreover, any number of cold plate assemblies may be used, including a single cold plate assembly.

Turning now to FIG. 2, a perspective view of a quadrant of cold plate assemblies 200 that are plumbed together in accordance with exemplary embodiments is depicted. The quadrant of cold plate assemblies 200 includes four cold plates 202 interconnected via plumbing lines 104. A spring plate assembly 204 is depicted atop each of the cold plates 202. It will be understood by one skilled in the art that while one plumbing configuration is depicted in FIG. 2, many other configurations are possible to source and return a cooling fluid to each of the cold plates 202. In exemplary embodiments, the plumbing lines 104 are made primarily of noncompliant (e.g., low flexibility) tubing to create a robust structure that can be brazed together between the cold plates 202 to reduce the possibility of leaks. Plumbing the cold plates 202 together may facilitate cooling of multiple modules in a substantially planar fashion. Further details of the cold plates 202 and the spring plate assemblies 204 are provided herein.

Turning now to FIG. 3a, a perspective view of a cold plate assembly 300 is depicted in accordance with exemplary embodiments. In exemplary embodiments, the cold plate assembly 300 includes a cold plate 202 and a spring plate assembly 204. The cold plate 202 includes a top component 302 and a bottom component 304. A cooling fluid circulation path, described in greater detail herein, may run internally through the cold plate 202 between plumbing ports 306. In exemplary embodiments, the two plumbing ports 306 are located at diagonally opposing corners of the top component 302 of the cold plate 202, providing inlet and outlet points for

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a cooling fluid to circulate through the cold plate 202. While two plumbing ports 306 are depicted on the cold plate 202, multiple plumbing ports 306 may be included in the cold plate 202 (e.g., multiple zones), providing inlet and outlet points on any surface of the cold plate 202. Moreover, the plumbing ports 306 may be located at any position relative to each other, e.g., adjacent. To assist in alignment and placement of the components of the cold plate 202, a guide marker may be placed at one or more location on the cold plate 202, such as guide marker 308 on the bottom component 304. In exemplary embodiments, the guide marker 308 is located near a plumbing port 306 to aid in orienting the top component relative 302 to the bottom component 304 when mating the top and bottom components 302 and 304. The guide marker 308 may be, for example, a hole, a raised element, or a printed indicator.

In exemplary embodiments, the cold plate 202 is placed atop a module 310, providing a heat transfer path to cool the module 310 for thermal stability of the module 310. The module 310 may include a variety of electronic components such as one or more microprocessors, memory, busses, and the like. In exemplary embodiments, the module 310 is a multi-chip module (MCM) with multiple chip subcomponents encapsulated in a single package. While the module 310 is depicted as a single package, it will be understood that the module 310 may also include multiple mechanical subcomponents which may be separable from the module 310, such as a lid, lateral supports, substrate material, and the like. The module 310 may utilize any packaging and interfacing technology known in the art, such as a PGA, BGA, LGA, or hybrid LGA module. The module 310 may make electrical contact with the PWB 102 via a socket 312. Although the socket 312 obstructs a direct view of the module 310 in FIG. 3a, the distinction between the socket 312 and the module 310 is apparent in FIG. 3b. In exemplary embodiments, the socket 312 acts as an interface between the module 310 and the PWB 102, and can vary in design based on the module technology. For example, the socket 312 may include two-sided spring or pad interfaces when the module 310 is an LGA, or one side of the socket 312 may include solder connections when the module 310 is a hybrid LGA. As the module 310 may require an actuation load to maintain electrical connections, the cold plate assembly 300 may further include one or more load arm 314 to hold the spring plate assembly 204 in place above the cold plate 202.

While the cold plate assembly 300 is depicted with two load arms 314, it will be understood that any number of load arms 314 with a variety of designs may be used within the scope of the invention (e.g., 1, 2, 4). For example, one or more of the load arms 314 could be designed as a post, a clip, or a hinge member. In exemplary embodiments, each load arm 314 is coupled to a hinge plate 316. Each hinge plate 316 may be attached to the PWB 102 using any fastening method known in the art (e.g., through-hole fasteners). In exemplary embodiments, the coupling of the load arm 314 to the hinge plate 316 provides a pivot point such that the load arm 314 can pivot outwardly, thus simplifying placement and removal of the cold plate 202 and the spring plate assembly 204 above the module 310.

In exemplary embodiments, the spring plate assembly 204 includes two spring plates 318 and an actuation screw 320. Actuation may be provided by fixed travel of the actuation screw 320 through the spring plates 318. While the exemplary spring plate assembly 204 includes a single actuation screw 320 and two spring plates 318, it will be understood that the scope of the invention is not so limited. To the contrary, there may be multiple screws, or similar coupling means, and any

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number of spring plates, laminated or otherwise, within embodiments of the present invention. For example, in applications that require an increased actuation load, additional spring plates **318** can be added to the spring plate assembly **204**, while applications with a lower actuation load requirement may use a single spring plate **318**. The spring plate assembly **204** may have vertical slots **322** at either end of the spring plate assembly **204**. The vertical slots **322** allow for adjustment and travel of spring pins **324**. The spring pins **324** may apply a force at each end of the spring plates **318**. In exemplary embodiments, each spring pin **324** is located above an end of the spring plates **318**, providing an attachment point for each load arm **314**.

In exemplary embodiments, the module **310** is seated on the socket **312**, the cold plate **202** is placed on top of the module **310**, and the spring plate assembly **204** is placed on top of the cold plate **202**. An actuation load may be applied to the cold plate **202** via the spring plate assembly **204**. In exemplary embodiments, the actuation load is configured to mechanically actuate the cold plate **202** to the module **310**. The load arms **314** can be locked down onto the spring pins **324** of the spring plate assembly **204**, thus maintaining the actuation load on the cold plate **202**. The actuation screw **320** may be adjusted to increase or decrease the actuation load. Although a range of actuation load forces may be applied, the actuation load force achieved through locking the spring plate assembly **204** on the cold plate **202** may be about 200 to about 300 lbs. The actuation load may be adjusted depending on the number of connections required between the module **310** and the socket **312**. For example, if the module **310** is a hybrid LGA module, the required actuation load may be about 60 grams per electrical connection point. In exemplary embodiments, the actuation load maintains a thermal interface material gap thickness **326** of about 30 to about 50 microns between the bottom of the cold plate **202** and the top of the module **310**. Moreover, the actuation load may be adjusted to account for varying height differences between modules **310**, as different modules **310** are manufactured within a tolerance range, and the modules **310** may include chips or cores of varying heights. The actuation load may also be adjusted to account for additional forces imparted by plumbing lines, such as the plumbing lines **104** of FIG. 2, connected to the plumbing ports **306** when multiple cold plate assemblies are plumbed together, as depicted in the quadrant of cold plate assemblies **200** of FIG. 2.

Turning now to FIG. 3b, an exploded view of the cold plate assembly **300** is depicted in accordance with exemplary embodiments. FIG. 3b provides an enhanced view of the cold plate **202** and the spring plate assembly **204** separated and raised above the module **310**, making the thermal interface material gap thickness **326** more apparent. In exemplary embodiments, a thermal interface material, such as thermal grease, is placed or applied in the thermal interface material gap thickness **326**, thus enhancing heat transfer between the cold plate **202** and the module **310**. FIG. 3b further depicts the pivoting motion of the load arms **314** relative to the hinge plates **316**, as the load arms **314** are pivoted outwardly to ease placement and removal of the cold plate **202** and the spring plate assembly **204** on the module **310**.

Turning now to FIG. 4, a top view and side cross sectional views of the structure of the cold plate **202** and the spring plate assembly **204** are depicted in accordance with exemplary embodiments. Sections A-A and B-B provide side cross-sectional views of the cold plate **202** and the spring plate assembly **204**. In section A-A of FIG. 4, a cooling fluid reservoir **402** can be seen as gap between the top and bottom components **302** and **304** of the cooling plate **202**. In exem-

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plary embodiments, the plumbing ports **306** depicted in section A-A, are brazed to the bottom component **304** of the cold plate **202**, providing structural stability while reducing the risk of leaks. The plumbing ports **306** may also be brazed or otherwise coupled to the top component **302** of the cold plate **202**. Section A-A further depicts other details previously described, such as the structural relationship between components of the spring plate assembly **204**.

Section B-B of FIG. 4 depicts cooling fins **404** that run through the cooling fluid reservoir **402**. In exemplary embodiments, the cooling fins **404** are integral with the bottom component **304** of the cold plate **202**, as depicted in detail C. The dimensioning depicted on various views in FIG. 4 is provided merely for purposes of example, and should not be viewed as limiting in scope, as the various components depicted can be scaled based upon a particular application (e.g., various module sizes, actuation load requirements, cooling fluid flow requirements, and the like). In exemplary embodiments, structural stability of the cold plate **202** is achieved through brazing the cooling fins **404** to the top component **302** of the cold plate **202**. Brazing the cooling fins **404** may enable the cold plate **202** to withstand a high actuation load associated with various module designs, such as a hybrid LGA (e.g., actuation load of about 200 to about 300 lbs.), and thus providing cold plate stability. Brazing the cooling fins **404** to the top component **302** of the cold plate **202** may further enable center point actuation, providing a substantially uniform a thermal interface material gap thickness **326**. Brazing the cooling fins **404** to the top component **302** of the cold plate **202** may further contribute to a low deformation rate of the cold plate **202** and the cold plate assembly **300**, providing substantially uniform deformation, and thus making coupling of multiple assemblies possible, such as the quadrant of cold plate assemblies **200** of FIGS. 1 and 2. Moreover, brazing may also provide enhance durability and resistance to corrosive effects associated with long-term contact with a cooling fluid, such as water.

Turning now to FIG. 5, a top cross sectional view of the structure of a channel and manifold for a cold plate **202** is depicted in accordance with exemplary embodiments. Section D-D of FIG. 5 illustrates an exemplary cooling fluid circulation path **502** through the cooling fluid reservoir **402** and the cooling fins **404**. The cooling fluid reservoir **402** may include all gap space in the bottom component **304** of the cooling plate **202**, not otherwise occupied by the cooling fins **404** or the plumbing ports **306**. In exemplary embodiments, the direction of flow and flow rate through the cooling fluid circulation path **502** can be adjusted by varying the inlet and outlet pressure at the plumbing ports **306**. As previously described, the approximate location of the plumbing ports **306** may be identified as the corner nearest to the guide markers **308**.

Turning now to FIG. 6, a flow diagram describing a process **600** for providing cold plate stability is depicted in accordance with exemplary embodiments. For ease of explanation, the process **600** is described in reference to the cold plate assembly **300**, with the cold plate **202** and spring plate assembly **204** as depicted in FIGS. 2-5; however, the process **600** is not so limited to the depicted embodiments. In exemplary embodiments, the cold plate **202** includes at least two plumbing ports **306**, providing an inlet and an outlet for a cooling fluid. The cold plate **202** may further include the top component **302** and the bottom component **304**. At block **602**, the cold plate **202** includes cooling fins **404** internal to the cold plate **202**, the cooling fins **404** brazed for providing internal stability for the cold plate **202**. The cooling fins **404** may be integral to the top or bottom component **302** and **304** of the

cold plate **202**, with brazing applied between the cooling fins **404** and the non-integral component, e.g., the cooling fins **404** may be cast as features of the bottom component **304** and brazed to the top component **302** for enhanced internal structural stability of the cold plate **202**. In exemplary embodiments, the cooling fins **404** provide a cooling fluid circulation path **502** between the at least two plumbing ports **306**. The cooling fluid reservoir **402** may also be part of the cooling fluid circulation path through the bottom component **304** of the cold plate **202**.

At block **604**, the cold plate **202** is placed in contact with the module **310**. As previously described, the module **310** may utilize any packaging and interfacing technology known in the art, such as a PGA, BGA, LGA or hybrid LGA module. In exemplary embodiments, the module **310** interfaces with the socket **312**, which is positioned on the PWB **102**. A thermal interface material, such as thermal grease, may be applied to the top of the module **310** or the bottom of the cold plate **202** to enhance heat transfer through the thermal interface material gap thickness **326**.

At block **606**, an actuation load is applied to the cold plate **202** via the spring plate assembly **204**. In exemplary embodiments, the spring plate assembly **204** includes at least one spring plate **318** and actuation screw **320**, the actuation screw **320** adjustable to set the actuation load. The actuation load may also be influenced by the spring pins **324** and the movement of the spring pins **324** within the vertical slots **322**. In exemplary embodiments, the actuation load is centrally applied relative to the cold plate **202** with internally brazed cooling fins, establishing a substantially uniform thermal interface material gap thickness **326**.

At block **608**, the spring plate assembly **204** is secured with at least one load arm **314**. In exemplary embodiments, the at least one load arm **314** is secured to the PWB **102** via a hinge plate **316**. The secured spring plate assembly **204** translates the actuation load to the module **310** via the cold plate **202**, providing external stability for the cold plate **202**. The process **600** may further include connecting a plumbing line **104** between one of the at least two plumbing ports **306** and a plumbing port **306** of a second cold plate **202**, forming an interconnected assembly, such as that depicted in the quadrant of cold plate assemblies **200** of FIG. 2.

Technical effects of exemplary embodiments of the invention may include applying an actuation load to maintain electrically connectivity to a module, such as a hybrid LGA module, while providing fluid cooling. Further technical effects include support for multiple assemblies plumbed together, providing a scalable solution for varying application scope. The use of brazing on internal cooling fins within a cold plate may provide substantially low and uniform deformation through enhanced structural stability, while enabling the cold plate to withstand high actuation loads.

While the invention has been described with reference to exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first, second, etc. are used to distinguish one element from another. Furthermore, the use

of the terms a, an, etc. do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item

What is claimed is:

1. A method for providing cold plate stability, comprising: placing the cold plate in contact with a module; applying an actuation load to the cold plate via a spring plate assembly, the spring plate assembly comprising a spring plate and a spring pin moveable in a slot of the spring plate assembly to maintain the actuation load; and securing the spring pin of the spring plate assembly to at least one load arm, the secured spring plate assembly translating the actuation load to the module via the cold plate.
2. The method of claim 1 wherein the cold plate includes at least two plumbing ports, the plumbing ports providing an inlet and an outlet for a cooling fluid.
3. The method of claim 2 further comprising connecting a plumbing line between one of the at least two plumbing ports and a plumbing port of a second cold plate.
4. The method of claim 2 wherein the cold plate includes cooling fins within the cold plate, the cooling fins providing a cooling fluid circulation path between the at least two plumbing ports.
5. The method of claim 4 wherein the cold plate further comprises a top component and a bottom component, the bottom component including the cooling fins and a cooling fluid reservoir, and further wherein the cooling fins are brazed to the top component.
6. The method of claim 4 wherein the cold plate further comprises:
 - a top component including the cooling fins; and
 - a bottom component, wherein the cooling fins are brazed to the bottom component.
7. The method of claim 1 wherein the spring plate assembly includes a second spring plate and an actuation screw, the actuation screw adjustable to set the actuation load.
8. The method of claim 1 wherein the at least one load arm is coupled to a hinge plate, the hinge plate providing a pivot point to pivot the at least one load arm to place and remove the cold plate and the spring plate assembly in relation to the module.
9. The method of claim 1 wherein a thermal interface material gap thickness is established between the cold plate and the module.
10. A method for providing cold plate stability, comprising:
 - placing the cold plate in contact with a module, the cold plate comprising:
 - at least two plumbing ports, the plumbing ports providing an inlet and an outlet for a cooling fluid;
 - a top component coupled to a bottom component; and
 - cooling fins brazed to at least one of the top component and the bottom component, wherein the cooling fins provide a cooling fluid circulation path between the at least two plumbing ports;
 - applying an actuation load to the cold plate via a spring plate assembly, the spring plate assembly comprising at least one spring plate, at least one spring pin, and an actuation screw, the actuation screw adjustable to set the actuation load; and
 - securing the at least one spring pin of the spring plate assembly to at least one load arm, the secured spring plate assembly translating the actuation load to the module via the cold plate.
11. A method for providing cold plate stability, comprising:

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placing the cold plate in contact with a module, the cold plate comprising:
a top component including at least two plumbing ports, the plumbing ports providing an inlet and an outlet for a cooling fluid; and
a bottom component comprising cooling fins brazed to the top component, the cooling fins providing cooling fluid circulation path between the at least two plumbing ports;
applying an actuation load to the cold plate via a spring plate assembly, the spring plate assembly comprising

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two spring plates in a stacked configuration, a pair of spring pins at opposite ends of the two stacked spring plates, and an actuation screw adjustable to set the actuation load; and
securing the pair of spring pins of the spring plate assembly to load arms, the load arms coupled to hinge plates to pivot the load arms, the secured spring plate assembly translating the actuation load to the module via the cold plate.

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